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ANNUAL REPORT

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"Physics and Technology for the In-Situ Investigation of Properties of Materials"

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and

R.C. Richardson, Co-Principal Investigator.

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Dated: 12/May/1988.

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Progress:

In the past year, the program has been taken from its inception to investigating effects of finite size in several materials. We have built and modified apparatus at Cornell, and obtain samples fabricated at the NNF or at Bell Labs, with whom we have a collaborative effort. Much of the data described here is preliminary.

The progress report is broken up into four sections, the first detailing the apparatus constructed, the second, results on $CoSi_2$, and third, very recent results on free standing Aluminium films and wires. In addition, results on As doped Si are proceeding and are described briefly.
Arsenic Silicon

1. Apparatus:

We have designed and built compact cryostats which can be cooled to ~1.2K by immersion in a storage dewar. The design was adapted from a simpler design used in Professor Pohl's group. We have recently added a superconducting solenoid which can generate 2.5T in the storage dewar. The cryostat is extremely compact, allows rapid thermal cycling to low temperatures, and can be easily operated to temperatures in excess of 100K. This mode is used for debugging the techniques and sample holders, as well as to carry out high temperature resistivity measurements which are useful in characterizing the sample. For the silicides, this cryostat is also used to take data on the log T dependence of the resistivity.

The same samples can be inserted into our Oxford 200 top loading dilution refrigerator cryostat which has been modified to include a 7T magnet mounted on the mixing chamber. We also have a small independently operated solenoid which is used to ramp the magnetic field slowly, and to provide a "zero field "environment, by nulling out trapped fields in the main solenoid. This apparatus allows us to carry out transport measurements down to below 20 mK (5 mK in zero field), provided that the sample holders are properly heat sunk. The samples are mounted on standard transistor TO-5 packages which are plugged in to the sample holder carrier ("slug"), and top loaded into the refrigerator. We have designed special slugs which allow us to carry out transport measurements with the field parallel or perpendicular to the substrate. A single computer controlled temperature sweep takes approximately 12 hours from 20mK to 1.3K, and the cycle time from loading to lowest temperature is ~ 8 hours.

2. Transport in Thin $CoSi_2$ Overlayers:

ANGSTROM COBALT Silicide

We have carried out measurements on several samples of $CoSi_2$. The first was on a 170Å thick layer where we observed that the material had a resistance ratio of $\sim$5.5, with a superconducting transition at $\sim$1K (mid point

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approximately

0.75K), (see figure 1a),and a critical field of ~100 G. In this sample, we have observed a shallow minimum in resistance at 4.5 K (figure 1b) with a log T low temperature resistance in the normal state. The degree of disorder in this sample inferred from the coefficient of the logT low temperature resistance is consistent with the degree of disorder expected from weak localization, and is also consistent with that observed in measurements of the other samples.

We find that there is no superconducting transition for the 84Å material. However the degree of disorder is similar to that observed in the 170Å film. The log T dependence is more pronounced as is expected, with a resistance minimum at ~15K as shown in figure 2a. In figure 2b, we illustrate the log T behavior to ~.2 K. The flattening at low temperatures is due to poor thermal contact in this early data.

Our interest is to pursue the question of the quenching of the superconducting transition due to size effects and disorder. To do this we will measure the behavior of samples of thickness greater than 84Å to map out the size dependence of T_c. In addition we plan to measure the log T dependence in both parallel and transverse magnetic fields to attempt to separate contributions from electron-electron interactions and weak localization.

3. Free Standing Films and Wires:

These are recent experiments that we have started on materials which have a phonon spectrum that reflects their reduced dimensionality. An aluminium wire or film is deposited on a silicon nitride substrate. The wire has six leads, two for current and four taps for voltage. Two of the voltage leads are used to monitor the voltage drop across a segment of the wire on the substrate, while the remaining pair straddle a section of the aluminium wire which has the substrate undercut from below it. This section (free-standing) and its companion (supported) are a continuous wire of identical composition, allowing us to study effects due to the free-standing material in contrast to those of a supported substrate. The conducting material is 200Å thick, and we have measured samples which are 50μm and 10μm wide as well as some earlier work with 0.2 wide wires.

We anticipated observing different electron heating effects in the two samples, since the electron-phonon interaction would be different due to the different dimensionality. However, in the samples that we have looked at, we find that there is a unique signature at the superconducting transition temperature. (The temperatures shown in the accompanying graphs are uncorrected and are in error by ~0.1K because of thermal gradients). The measurements are described briefly below.

In fig 3 we show the resistance of the *free standing* wire segments for both 50 and 10μm widths in low magnetic fields. The shoulder on the data from the 50μm wide material is probably an artifact of the local magnetic field.

The most striking feature is the abrupt increase in resistance near the transition temperature. This feature is not present on the wire which is *supported*. When a field of 1 kG is applied to the 10μm wide sample, transverse to the conduction path, we observe that the resistance of the free standing part increases by ~15%, and saturates at low temperatures. In contrast the resistance of the supported film decreases, exhibiting a broad transition. This behavior is shown in figure 4a and 4b. In higher magnetic fields (10 kG) both the free standing and supported films behave as normal metals. We are unsure as to the origin of this behavior, and are attempting to look at more samples to pin down the phenomenon.

4: Arsenic doped Silicon:

By doping silicon with arsenic, the resulting conductor is seen to exhibit characteristics of weak localization. Studies of this system have been initiated , and the sample prepared by ion implantation, shows a resistance minimum at 20K and a logT temperature dependence below that temperature. The magnetoresistance shows signatures which are consistent with the weak localization picture, with an increase in the conductance at low field, switching to a more classical increased magnetoresistance at high fields. Electron heating measurements are in progress on these samples. This research is being conducted with its major support from the SRC.

Publications:

J. DiTusa, J.M.Parpia and J.M.Phillips, " Electrical Transport in Thin $CoSi_2$ Films", Bull. Am. Phys. Soc., 33, 494, 1988 .

Fig 1a) Resistance of 170Å $CoSi_2$ film in three magnetic fields. (note suppressed zero).

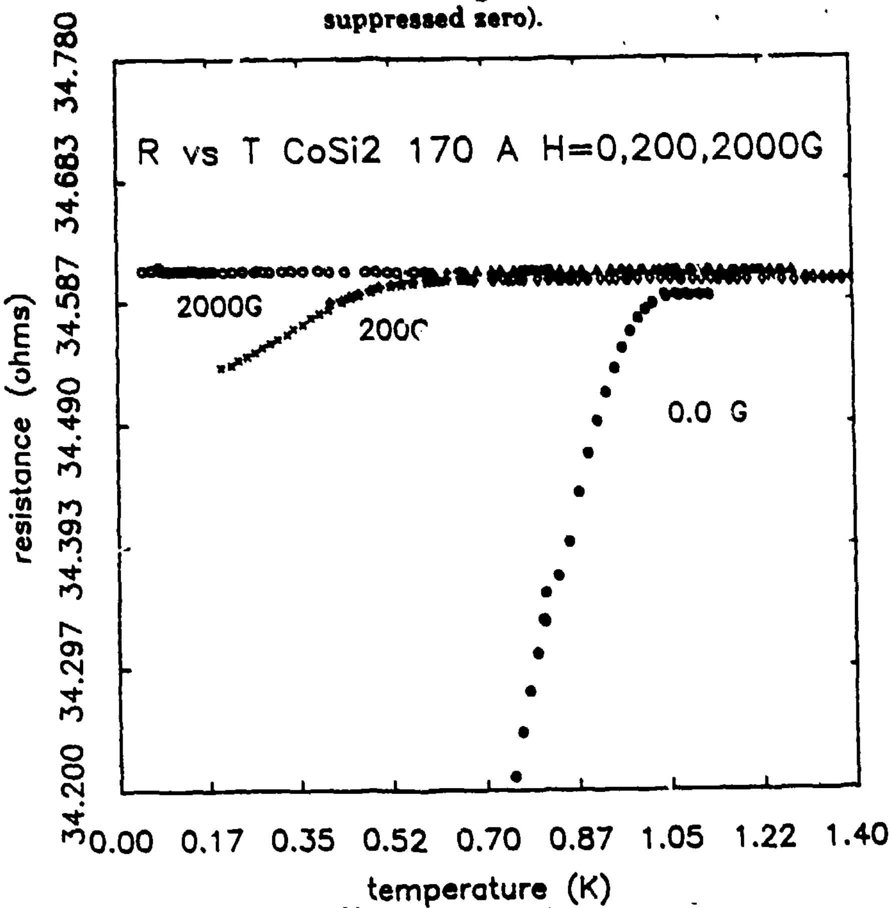


Fig 1b) Resistance of 170Å $CoSi_2$ film in zero field at high temperature showing a clear resistance minimum, and onset of superconducting fluctuations at ~2K.

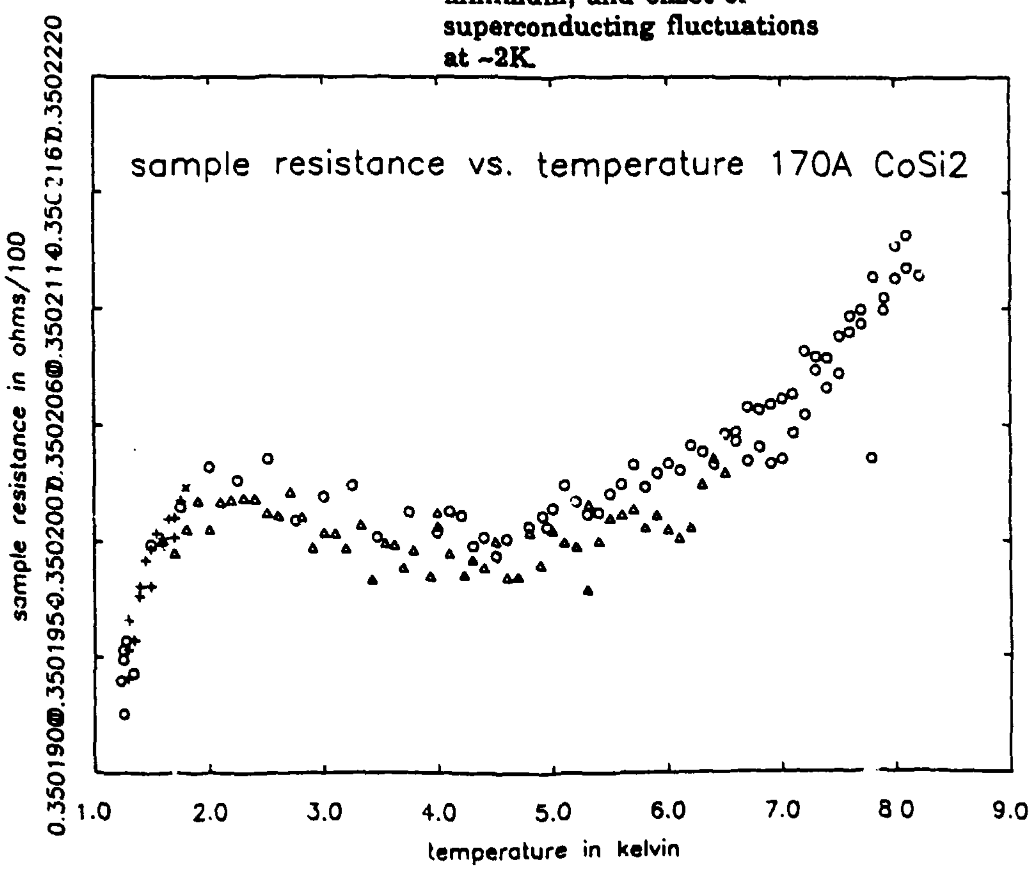


Fig 2a) The resistance of 84Å thick film plotted below 20K. Note the resistance minimum at ~18K, and sharp rise at low temperatures.

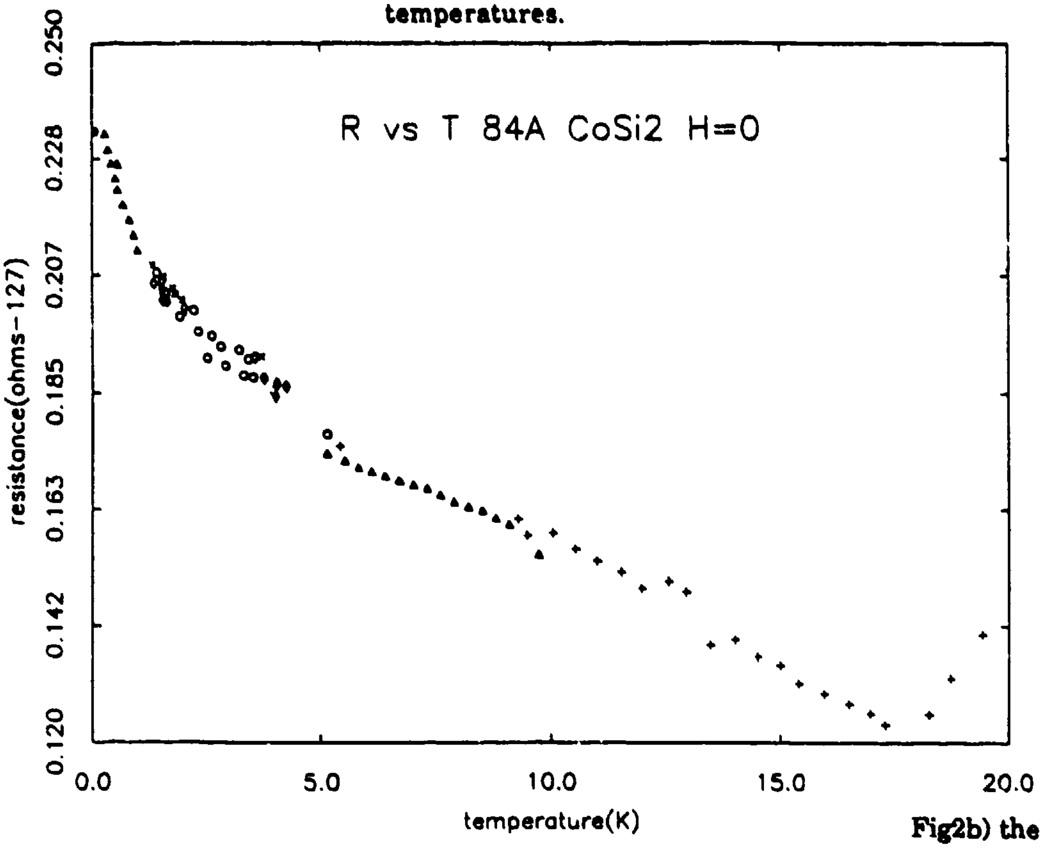
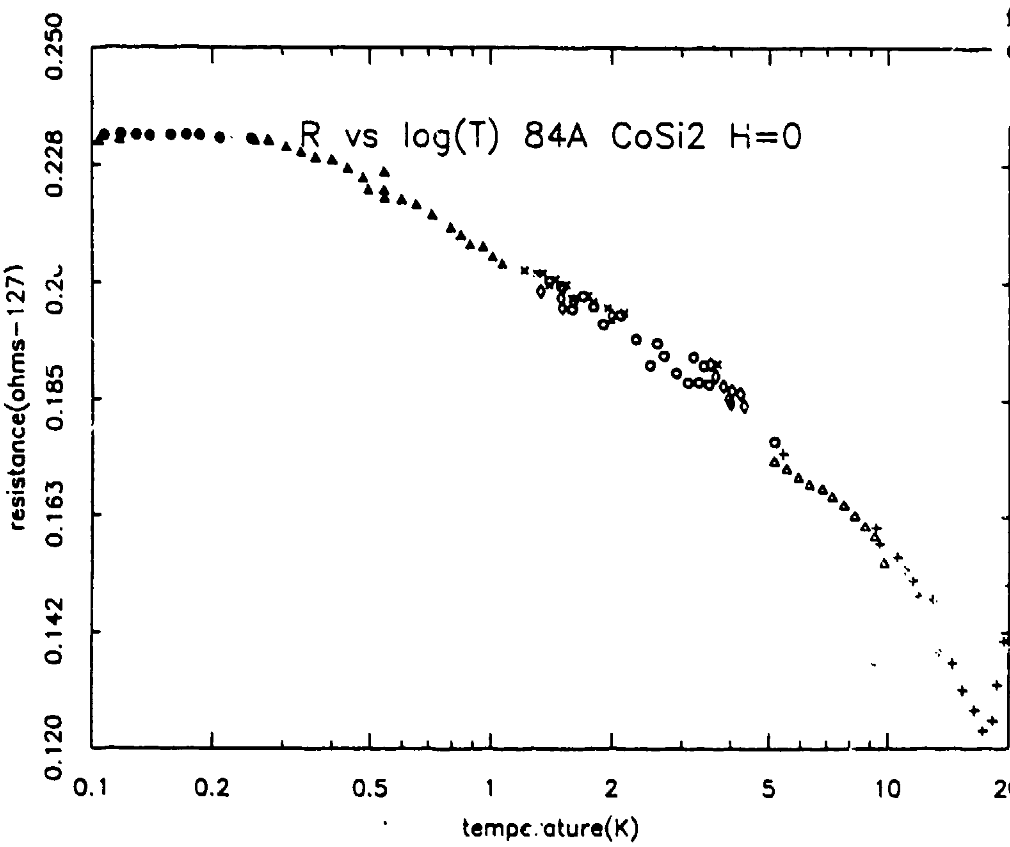


Fig2b) the same data as in fig 2a, plotted against the log of temperature. Between 10K and 0.2K, the data fits the log T dependence characteristic of weak localization or electron interactions. The flattening at 0.2K is due to loss of thermal contact.



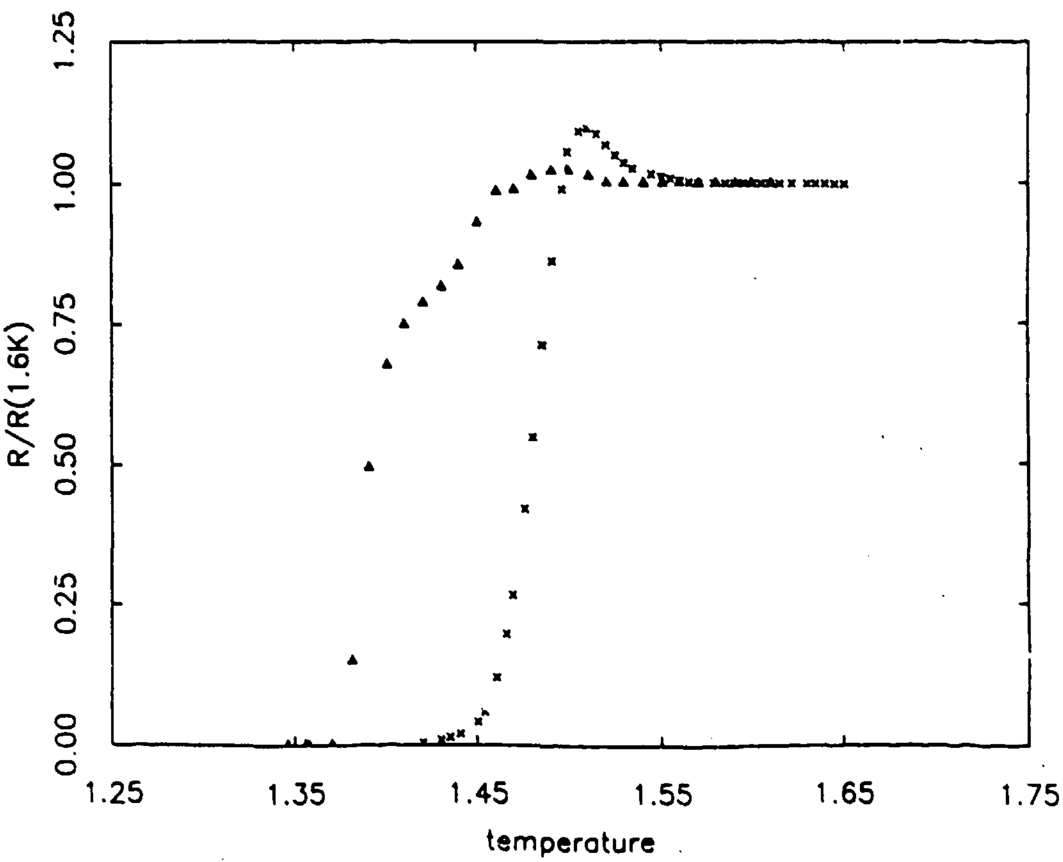


Fig 3) We plot the resistance of 10μm (x)and 50μm (Δ) wide 200Å thick free standing Al films, in low magnetic fields. The shoulder in the 50μm data may be due to magnetic field effects.

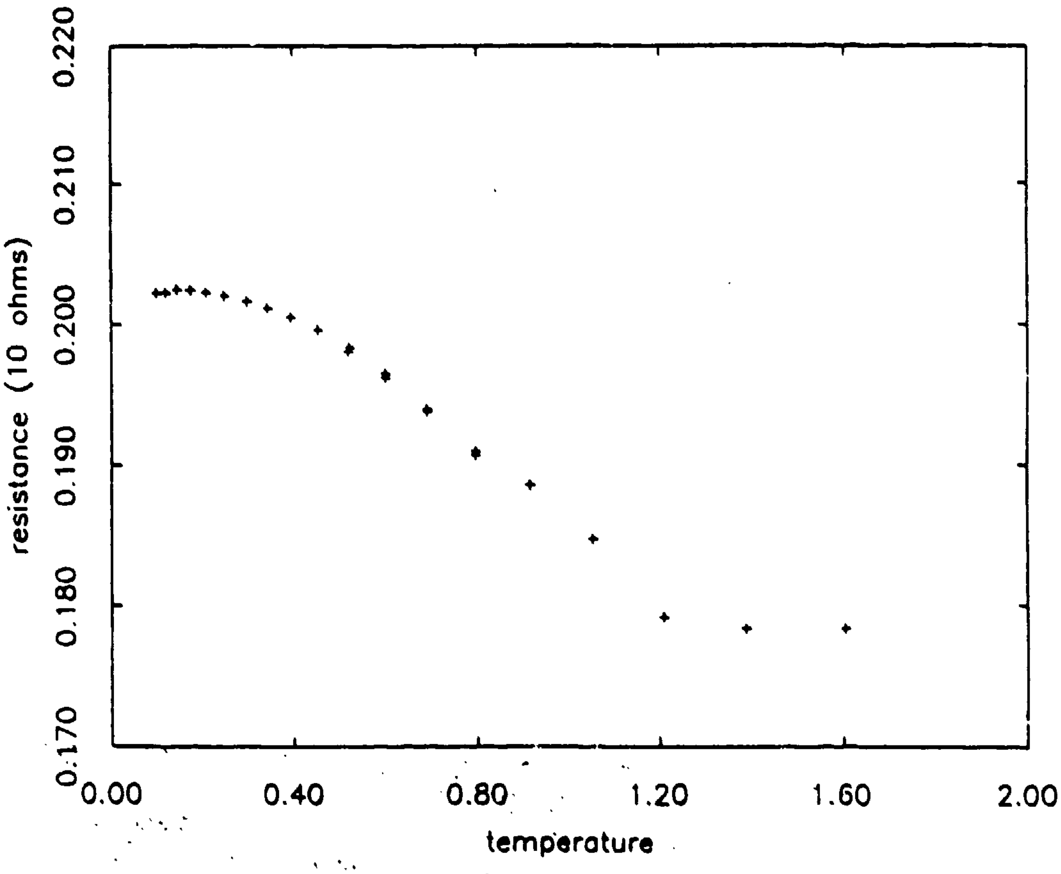


Fig 4 **a)The resistance of a 50μm free standing film in 1kG. The fresistance increase is ~ 15%. This behavior is contrasted to that for the same film on the substrate (b).**